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ABSTRACT

This paper presents the design, implementation, and evaluation of an interactive hypermedia math program which focuses on multiplication and problem solving. The program contains a thematically meaningful story about a lost dog named Addy. The work is based on instructional design principles defined by Walter Dick and Lou Carey (1990) in their book "The Systematic Design of Instruction". Upon completion, the math program was implemented and evaluated in a combined second and third grade classroom. The evaluation of the program provides support for the integration of computer assisted instruction into the elementary math curriculum. Computer-generated slides are presented along with a student evaluation form. (Author/NB)

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The Design and Implementation of a Hypermedia Math Program

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Abstract

This paper presents the design, implementation, and evaluation of an interactive hypermedia math program which focuses on multiplication and problem solving. The program contains a thematically meaningful story about a lost dog named Addy. The designers of the program based their work on instructional design principles defined by Walter Dick and Lou Carey (1990) in their book The Systematic Design of Instruction. Upon completion, the designers implemented and evaluated the math program in a combined second and third grade classroom. The evaluation of the program provides support for the integration of computer assisted instruction into the elementary math curriculum.

CHAPTER ONE: INTRODUCTION

In their 1990 survey of reputed computer-using teachers, Karen Sheingold and Martha Hadley found that some teachers at all grade levels use computer software to enhance the curriculum with intellectually exciting educational experiences. These teachers abandoned the traditional view of computers as substitutes for paper and pencil worksheets and as rewards for those that complete their classwork. Instead, these teachers employed a wide variety of computer software including simulations, graphing programs, writing tools, communications software, and problem solving programs to address curricular goals.

While there are numerous software programs available to educators, these programs do not meet every classroom's needs. Trying to instruct a class of students using a computer program that is either too difficult or not engaging enough is much like trying to dress a small child in clothes that are too small or too large. Ultimately, despite persistent effort, the child is no better off and very uncomfortable. This was the situation in a combined second and third grade classroom in Albemarle County, Virginia. The classroom teacher was unsuccessful in her search for math software that reinforces multiplication concepts. The software she found had too much text for the students to read and did not engage the students.

In order to help the teacher with this problem, we decided to apply our knowledge of instructional technology and to create software that would fit this classroom's needs. Our mission was to develop a fun, educational, and user friendly math program to reinforce multiplication in the context of problem solving. We wanted to present the concepts in this context because of the current emphasis on incorporating problem solving into all areas of math education.

To accomplish our mission, we researched and applied a variety of principles for developing instruction. Chapter Two will present our findings on designing instruction in general and will discuss specific applications of these ideas to software design. Chapter Three will follow with a discussion of how we applied these principles to our program. In Chapter Four, we will offer the evaluation of our program. We conclude with Chapter Five in which we will summarize the study and discuss implications for teaching and future research.

CHAPTER TWO: REVIEW OF INSTRUCTIONAL DESIGN LITERATURE

Research indicates that important design considerations for authoring a hypermedia program are similar to those considerations taken when writing a lesson plan. Good instructional design for lessons long preceded computers in the classroom. To arrive at current beliefs about design, "we have taken what is known about designing good instruction and added to it what we have learned about the power of the visual" (Dana and Handler, 1995, p.252). The following paragraphs contain currently accepted design considerations for creating effective instruction. The steps toward developing effective instruction are: identify the instructional goal, identify the audience, determine the instructional strategy, develop instructional materials, and conduct a formative evaluation. These principles are adapted from and are based primarily upon Walter Dick and Lou Carey's (1990) work, The Systematic Design of Instruction. Specifically, we discuss incorporating these principles into software design.

Identify the Instructional Goal

Instruction is the solution to a problem. Design begins, therefore, with the determination of this problem and the subsequent determination of the instructional goal. Problems should be identified through what Dick and Carey (1990) call a needs assessment. This assessment identifies a gap between what is and what should be.

Identify the Audience

Once the instructional goal has been identified, a designer must turn his or her attention to the audience or the "target population" that he or she is aiming to "hit" with instruction. The entry behaviors and characteristics of the audience is essential information. "In order to have effective instructional materials or, for that matter, any type of successful instructional

experience, there must be a match between students and instruction" (Dick and Carey, 1990, p.83).

In any group that is receiving instruction, there will be variation. Learner characteristics are, therefore, described in terms of the average student. Necessary information about the target group includes age, grade level, and knowledge. Also relevant to instruction are the interests of the group. Dick and Carey caution designers, however, about making generalizations in terms of these learner characteristics.

> Too often designers make references about the characteristics of the learners without actually verifying them. Based upon stereotypes of the learners it might be assumed that fourth grade boys would be interested in baseball...Quite often these assumptions reflect the interests of the designer ...and are not at all reflective of the target population. Therefore it is important to observe and interview members of the target population to determine not only their status, vis-à-vis the entry behaviors, but their general ability level, previous experiences, and expectations about instruction (Dick and Carey, 1990, p. 89).

In addition to learner characteristics, the designer must determine the entry behaviors or skills that must be mastered before beginning instruction. These entry behaviors are the initial blocks upon which the instruction will be built. Entry behaviors are not simply a list of all things that the students know or can do. They should include only those skills related to the topic and, consequently, necessary to begin the instruction. At this stage, the designer can err in one of two directions. First, if the instruction is designed for only the brightest students in a population, the majority of the students will not possess the entry behaviors needed to benefit from the

instruction. When this happens, the instruction will be ineffective because the students will become frustrated. On the other hand, the designer could assume that the target audience has few or no skills when in actuality they already possess much of the knowledge covered in the instruction. This poses a problem because time is wasted as learners study objectives they have already mastered. Thorough knowledge of the learners will alleviate the chance of these errors.

Determine the Instructional Strategy

After determining the instructional goal and describing the target population, the designer must generate an instructional strategy. The designer knows where he or she is going, who he or she is taking, and is now left to plan the course. "An instructional strategy describes the general components of a set of instructional materials and the procedures that will be used with those materials to elicit particular learning outcomes from the students" (Dick and Carey, 1990, p.162). The five major components of an instructional strategy include: preinstructional activities, information presentation, student participation, testing, and follow through.

Preinstructional Activities

Prior to beginning instruction, there are three factors that a designer should consider. The first factor is motivating the students. The second factor is informing the students of what they will learn. The third factor is ensuring that the learners have the prerequisite knowledge and skills needed to begin instruction.

The level of student motivation is a key determinant in the design process. Research gives particular emphasis to engaging students with problem-based learning. This model includes

> motivating the learner by demonstrating the practical applications and importance of the knowledge, providing a conceptual description of the skill, demonstrating the application

> of the knowledge to practical problems, providing practice opportunities with support in the form of scaffolding, and facilitating transfer through guided reflection on the activity to integrate the practical issues with the underlying conception (Quinn, 1997, p. 2).

While instruction may be able to gain a learner's attention for a short period of time, it is difficult to sustain this interest if the learner does not perceive that the material is relevant to him or her and that the material has practical implications for his or her life.

Considerable research has also been devoted to a discussion of multimedia's ability to engage and motivate learners.

> Engagement serves as the "bridge" to learners and is built best by ensuring that students can relate to the information (text and graphics) presented. The relationship of presented material to a learners existing knowledge base, each known as a link, is a critical success factor in using multimedia for instruction (McFarland, 1995, p.67).

In general, a person will learn better and be more motivated if many links to prior experiences are included in the current material.

Another concern prior to beginning instruction is informing the students of the objectives for instruction. Designers must tell the learners what is expected of them so that they can focus their study strategies and efforts on these outcomes.

The last factor to consider before starting instruction is ensuring that the learners have the prerequisite knowledge and skills needed for effective instruction. The purpose of this activity is to make certain that instructional time will not be wasted and that the learners have the means to accomplish the objectives.

Presentation of Information

Once the preinstructional activities have been completed, the designer is ready to consider the presentation or sequencing of the information. One appropriate method for sequencing is to begin with the lower level tasks and then progress to more difficult tasks. Another appropriate method is to construct a non-linear environment using hypermedia. This medium provides an exploratory learning system in which the learner controls the delivery of material. Stanton and Stammers (1990) suggest that the reasons why a nonlinear environment might be superior are that it (a) allows for different levels of prior knowledge, (b) encourages exploration, (c) enables subjects to see a subtask as part of the whole task, and (d) allows subjects to adapt material to their own learning style.

Also in terms of presentation, the designer must determine exactly what information, concepts, rules, and principles need to be presented to the learner. This implies a focus on the types and number of examples that will enhance the concept being presented.

Student Participation

The next major component in the instructional strategy is student participation and feedback. A powerful aspect of the learning process is practice with feedback. Feedback simply gives learners information about their performance. Shneiderman (1983) and Hutchins, Hollan & Norman (1986) suggest a tight coupling between action and feedback both in the form of the communication, and in the time between action and response. The nature of feedback is also important. "It should be balanced so that it focuses on both the successes and failures in the rehearsal. Focusing only on errors may cause learners to perceive that nothing they did was meritorious, which is seldom the case" (Dick and Carey, 1990, p.168).

Testing

At this point, the designer must decide what his or her strategy will be for testing. Tests are a valuable communication device that lets the learners know how they are progressing through the material. Issues such as when during instruction the test will be administered, what skills it will cover, and the what form it will take are important considerations for the designer.

Follow Through

Part of good instruction is developing follow-up activities for students to complete after instruction. Remediation may be necessary for those who struggle through the instruction and enrichment could be offered to the students who master the material with ease.

Develop Instructional Materials

The next step, after developing the instructional strategy, is to assemble the materials that will be used during instruction. A key suggestion at this stage is "don't reinvent the wheel." If someone has already developed materials that are appropriate for the delivery of instruction, the designer should use them. If no appropriate materials exist, the designer should begin the development process.

"One of the most interesting and challenging decisions in the instructional design process is the selection of the medium or media that will be used to deliver the instruction" (Dick and Carey, 1990, p.202). This decision depends on the designer's knowledge of what will be taught, how it will be taught, how it will be tested, and who the learners will be. Weiser and Gagne (1983) have published a flow chart that details how to choose the appropriate medium for instruction. While using the flow chart, the designer answers several questions that lead him or her to several media suggestions. Important factors for the designer to keep in mind when

choosing among these suggestions are projected availability of media and the cost effectiveness of the media.

Research on the best media to teach intellectual skills suggests that students should be provided precise corrective feedback to responses made during the instruction process. Dick and Carey (1990) agree that in order to provide responsive feedback, there is a need for such interactive media as computer based instruction.

Conduct a Formative Evaluation

Formative evaluation is the process used by instructors to gather data that will help them revise their instruction and make it more effective. Dick and Carey (1990) suggest a three phase evaluation process. The first phase is a one-to-one or clinical evaluation. The purpose of this phase is to remove the obvious errors and obtain initial reactions from a learner. The second phase of formative evaluation is the small group evaluation. The members of the small group evaluation team should be as representative as possible of the target population since this step gathers information about any remaining learning problems that actual students may encounter. The purpose of the final phase, the field trial, is to determine if the instruction can be used in the environment for which it was designed. For this reason, the designer must attempt to find a field situation that closely resembles the intended users' situation.

CHAPTER THREE: DEVELOPMENT OF OUR HYPERMEDIA MATH PROGRAM

Identification of Our Instructional Goal

The development of our hypermedia math program began with the identification of a problem and the subsequent determination of an instructional goal. A teacher at an elementary school in Albemarle County, VA was unsatisfied with the current math software programs available to her, primarily because the design of these programs did not match the needs of her students. As indicated by the teacher, her students had a tendency to lose interest in the programs because of large amounts of text, few opportunities for interaction, and inappropriate levels of challenge.

After extensive discussions with the teacher and with each other, we decided to help the teacher solve this problem by developing a math program that would meet the needs of her students. Our instructional goal was to create a program that would intrinsically engage the students and would lead them through an interactive experience that would enhance their ability to solve mathematical problems.

Identification of Our Audience

Once we identified the problem as well as our instructional goal, we focused our attention on the students for whom we were designing the program. Our first task was to identify the students' general characteristics and interests. Our second was to identify specific entry competencies such as knowledge, skills, and attitudes about our topic.

General Characteristics and Interest

The students involved with our math program were members of a second and third grade combination class and ranged in age from seven to nine years old. The class consisted of thirteen

girls and nine boys, all of similar ethnicity and socio-economic status. The ability levels of the students spanned from low ability (special needs) to high ability (gifted).

Through informal discussions and written autobiographies, the students indicated that they all shared a common interest in pets. The majority of the students had at least one pet at home and some had as many as three or four. They also indicated that they enjoyed traveling and visiting different locations.

Entry Competencies

At the onset of our field work, the students were in the process of learning multiplication facts for numbers 0-9. The teacher's goal was to move from this level of multiplication to two-digit multiplication by the projected completion of our math program. In addition to learning multiplication, the students were also learning to use the information presented in word problems to write and solve mathematical equations.

In regards to technology, the students demonstrated a solid knowledge base as well as advanced user skills. They were familiar with and could independently use the classroom computer's hardware as well as its software. Upon further investigation, we found that the students had an abundance of technology experience both in and out of the classroom. The teacher consistently and effectively integrated technology into her units of study. In addition, the majority of the students used computers in their homes for daily activities.

Informal discussions with the students and with the teacher revealed that the students held positive attitudes toward math as well as toward math software, as long as their experiences with these topics were "fun." When instruction did not provide an element of fun, the students had a tendency to lose interest and to develop negative attitudes toward math.

Identification of Our Instructional Strategies

After determining the instructional goal and describing our target population, we began to generate our instructional strategy. The following paragraphs are descriptions of the three general components that we used to create a math program that is engaging, interactive, educational, user-friendly, and fun. These components included preinstructional activities, presentation of information, and student participation.

Preinstructional Activities

Our preinstructional activities consisted of selecting strategies for motivating the students to use our program, for informing the students of their tasks, and for ensuring that the students had the prerequisite knowledge and skills needed to use the program.

Motivating the Students

Our first concern was motivating the students to use our program. In response to our research on student motivation, we decided to integrate into our program a thematically meaningful story line based on the students' common interest in owning pets. Specifically, we designed our story line to center around a lost dog named Addy who must be located by his owner (see Figures 1 and 2).

In addition to a thematically meaningful story line, we decided to integrate a problem-based learning model into our program to increase student motivation. The model we selected involved demonstrating the practical application and importance of the knowledge, providing a conceptual description of the skill, and demonstrating the application of the knowledge to practical problems.

In order to accomplish all of the tasks involved in the problem-based learning model, we decided to expand our story line by having the students look for Addy in different locations within a town (see Figure 2). At each of the locations, we opted to present the students with a "real-life" problem that required them to reflect on multiplication as it is used outside the classroom and to use their skills at a conceptual level (see Figure 3).

Informing the Students

Our second concern was informing the students of our objectives for the math program. We wanted the students to know exactly what we expected of them so that they could focus their strategies and efforts on those outcomes.

In order to specify our non-instructional objective, finding Addy, we choose to provide the students with a brief introduction and statement of purpose at the beginning of the program. The second screen contains a brief descriptions of the students' task while using the program. We tell the students what we want them to accomplish and how to be successful (see Figure 2).

When considering our instructional objective, enhancing the students' multiplication skills, we felt as though a brief introduction at the beginning of the program would not give the learners the opportunity to clearly understand our purpose. For this reason, we chose to conduct an informal discussion prior to implementing the program. In this discussion, we wanted to clearly communicate our instructional purpose and to clarify any misconceptions held by the students.

Prerequisite Knowledge and Skills

Our third concern was ensuring that the students had the prerequisite knowledge and skills needed to complete our program. Through informal interviews and observations, we found

that both the students' knowledge base and their skills were sufficient to accomplish our non-instructional as well as our instructional objectives.

Presentation of Information

Once we completed our preinstructional activities, we began to develop the second component of our instructional strategy, the presentation of our information. This component involved sequencing the information to be presented as well as selecting design principles and guidelines for effective presentation.

Sequencing the Information

We felt that a non-linear environment would be the best method for sequencing our information because it would provide the students with an exploratory learning system. They could explore the program at their own discretion and could control the delivery of material by choosing where they wanted to look for Addy. By making the students the locus-of-control and granting them a perception of choice, we believed that our efforts to instruct, engage, and interact with the students would be more effective.

Selecting Principles and Guidelines

In their book Instructional Media and Technologies for Learning, Heinich, Molenda, Russell, and Smaldino (1996) point out that some designers have a tendency to overemphasize text and to ignore the benefits of visual imagery. As a result, they create instructional environments that are neither engaging nor educational. To avoid this type of failure, we chose to follow certain principles and guidelines related to the effective use of visual imagery. The majority of these principles and guidelines were taken from the third chapter of Instructional Media and Technologies for Learning.

For the purpose of information and instruction, we focused our attention on three areas of visual design as suggested by Heinich et al. (1996): ensuring legibility of text and graphics, reducing the effort required to interpret the information presented, and increasing the students' active engagement with the information.

ensuring legibility of words and images.

A good visual cannot even begin to do its job unless all users can see the words. Our goal was to remove as many obstacles as possible that might impede the engagement and instruction of the students. To accomplish this goal, we employed design principles related to lettering style, size, and color.

When choosing the style of lettering, we elected to use a plain style that was consistent and harmonious with other visual designs. In addition, we used no more than two different lettering styles per screen (see Figure 1).

To further increase legibility, we used lowercase letters, adding capitals only where required. In HyperCard Stack Design Guidelines released by Apple Computer, Inc. (1989), the authors claim that it is much easier for people to read a mix of uppercase and lowercase letters than it is for them to read only uppercase.

Because lowercase letters are obviously smaller than uppercase letters, we knew that the size of our lettering would be crucial to the legibility of our screens. Following a guideline suggested by Heinich et al. (1996), we made our lowercase letters 1/2 inch high for each ten feet of viewer distance.

After making decisions about lettering style and size, we began to select the color of our lettering. We wanted the color to contrast with the background color both for the sake of simple

legibility and for the sake of emphasis. With this in mind, we decided to make the majority of our lettering black. We only used a different color when we wanted to draw the users attention to a specific word.

reducing effort.

As designers, we wanted to convey our information in such a way that the students would expend little effort making sense out of what they saw. The idea was to establish an underlying pattern that would decide how our user's eyes would flow across our screen.

Our first step was to position the primary elements within the screen so that they had a clear visual relationship to each other. We established this visual relationship by aligning the edges of our elements on the same imaginary horizontal or vertical line which was parallel to the edges of the screen.

Our second step was to put the visual elements into a shape that would be familiar to the viewer. Our goal was to use a pattern that would attract and focus the user's attention as effortlessly as possible. To accomplish this goal, we placed text at the top of the screen and graphics at the bottom whenever possible (see Figure 3).

Color can also make a difference in the effort required to interpret information. When designing our program, we followed two of McFarland's (1995) guidelines for using color to reduce effort. First, we used soft, non-intrusive colors such as pastels or soft grays for screen backgrounds. Eyes have a tendency to become fatigued when exposed to highly saturated colors for an extended period of time. Second, we used a consistent color scheme throughout the entire program. When a different color scheme was necessary for emphasis, we made sure that we selected colors which were complementary to our original scheme.

Without consistency, we knew that the guidelines related to alignment, shape, and color would be useless. Heinich et al. (1996) claim that as viewers go through a series of images, they begin unconsciously to form a set of rules about where information will be located on the screen. The more often the arrangement conforms to these rules, the more the viewers trust the rules. Every time the arrangement breaks the rules, the viewer has to expend mental energy deciding whether this is a deliberate exception or whether the rules need to be revised. To avoid this unwanted expenditure of mental energy, we placed similar elements in similar locations, used the same text style, and used the same color scheme throughout our program.

increasing active engagement.

When considering active engagement, one of our goals was to make our design as appealing as possible. We wanted to get the students' attention and to entice them into thinking about the information presented. The following is a summary of our attempts to capture and hold our users' attention and to actively engage them in the learning process.

Because users pay attention as long as they are getting novel stimuli or new information, we decided to incorporate as many different situations and problems as possible. Within four of the six locations in the town, we give the users at least two new and unrelated situations and problems. For example, while looking in the park, the users have the option of visiting the climbing tree to count apples, the bike trail to calculate traveling distance, or the picnic area to figure out how much food a family is missing (see Figures 4,5,6, and 7).

To further increase opportunities for active engagement, we provided users with the feeling of directly manipulating our program. We allowed them to respond to our visual display by manipulating objects and representations on the screen. In addition, we attempted to promote

active engagement by stimulating the curiosity of the user. Our most effective element for stimulating curiosity was the non-deterministic outcome of the program. The users never know where Addy is hiding.

Student Participation

In order for students to completely participate in the learning process, instructional methods and materials must provide opportunities for practice with feedback. Research indicates that a tight coupling between action and feedback is important both in the form of communication, and in the time between action and feedback. In addition, the feedback must be directly related to the action and must be balanced so that it focuses on both the students' successes and failures.

Applying these ideas to our program involved developing methods to provide rapid, relevant, and balanced feedback. Our first method was to use quick and non-intrusive transitions between screens to immediately inform the students of their success or failure in solving the selected math problem. We felt that this would eliminate the possibility of confusion and would keep the problem in the students' minds.

Our second method was to embed the feedback into the context in which the students performed the action. We wanted the feedback to be relevant and related to the problems that we asked the students to solve. To accomplish this goal, we decided to rely on visual images to relate actions and feedback. For example, if a problem involved money, then the student would have to click on money to receive feedback and to return to the problem (see Figures 8 and 9).

Our third method was to design separate yet related screens for different types of feedback. If the user selected an incorrect answer, we wanted them to arrive at a screen that

would encourage them to try again and to select the correct answer. We accomplished this by placing the statement "Oops! Not quite right. Try Again" on a dull and visually unattractive screen (see Figure 9). If the user selected the correct answer, we wanted them to arrive at a screen that gave them the perception that their efforts were meritorious. We accomplished this goal by placing the statement "Way to go! You are correct" on a visually exciting screen (see Figure 10).

Determination of Our Instructional Materials

The next step after developing our instructional strategy was to assemble the materials that we would need to complete our math program. These materials consisted of a storyboard, clip art, and a hypermedia program.

Storyboard

Before we sat down at the computer to actually design our math program, we spent a great deal of time designing a storyboard to help organize the sequence of our computer screens as well as the layout of each screen. We made simple sketches of the visuals that we planned to use and put them on individual index cards. We also included narration and production notes on these cards. Once we developed all of the cards, we color coded them according to their topic and mounted them in rough sequence on poster board.

Clip Art

After completing the storyboard, we began to search for images that we could use to represent our sketches. We felt that clip art images would be more effective than hand-drawn images because they are more attractive to the eye and because they would save us valuable time when creating the screens. With over 185,000 clip art images at our side, we found a match for every visual that we sketched on our storyboard. Unfortunately, some of the images we selected

were not sensitive to biases or stereotypes related to gender, ethnicity, ability, etc. Instead of discarding these images, we chose to edit them by changing those aspects that supported these biases and stereotypes.

Hypermedia Program

We based our decision to use HyperStudio on our familiarity with the program as well as on suggestions made by several technology instructors. We felt that HyperStudio would allow us to accomplish our instructional objectives and to employ our instructional strategies.

As our program approached completion, we discovered that we could not effectively hide and show different cards as needed. Our knowledge of HyperLogo, the scripting language for HyperStudio, was insufficient for us to accomplish this task.

Following the suggestion of a technology instructor, we transferred all of our work into a hypermedia program known as Oracle Media Objects (OMO). We found that the scripting language in OMO was much easier to use and that it would, in fact, allow us to hide and show the cards as needed.

Our Evaluation Procedures

The evaluation of our program occurred in three phases. The first phase involved a clinical evaluation in which we removed obvious errors and obtained initial reactions from a technology instructor. The second phase involved a field evaluation. While the targeted students used the program for the first time, we recorded informal observations of their experiences as well as their comments. The third phase involved a student evaluation survey in which we attempted to obtain information related content, motivation, and design (see Appendix).

Conclusion

In this chapter, we presented an in depth discussion of how we applied our research on designing instruction to the math program we created. The next chapter will elaborate on the evaluations of our program and will analyze the results of these evaluations.

CHAPTER FOUR: EVALUATION AND RESULTS

Introduction

As stated in Chapter 3, the evaluation of our math program consisted of three stages: a clinical evaluation, a field evaluation, and student evaluations. The following paragraphs will elaborate on these evaluations and will summarize the results.

Clinical Evaluation

Our clinical evaluation involved removing obvious errors in the program. These errors consisted of spelling mistakes, grammatical mistakes, and aspects that did not adhere to the design principles and guidelines we selected.

In addition to correcting errors, we also obtained initial reactions to our program from a technology instructor. As she used the program for the first time, she gave us valuable insight into one area of the program that might be confusing to the students. This area was navigation.

In our program, we placed invisible buttons over clip art and linked these buttons to other screens. We assumed that the students would know to click on these images to navigate through the screens. Our technology instructor pointed out that this assumption may cause confusion. For this reason, we elected to add labels that would tell the students exactly what to do as well as where to go.

Field Evaluation

After completing the program and conducting a clinical evaluation, we presented the program to the students for whom it was designed. We took the students to a computer lab where we asked them to use the program. While the students were working, we recorded as many of their comments as possible. Examples of the students' comments include: "I found Addy "X"

times", " Yes! We found Addy twice. This is an awesome game.", "I've already seen this problem so I know the answer."

In addition to recording comments, we also recorded informal observations of the students' experiences. We noticed that the students had difficulty when solving some of the math problems because they did not have a means of working them out by hand. Many of the students struggled to solve the problems in their heads instead of asking for paper or manipulatives. We also noticed that once the students solved a problem correctly, they had a tendency to remember the answer and automatically click on it upon returning to the screen. They did not waste any time reading or solving the problem again.

The implications of these results are numerous. First, we need to provide the users of our program with a means of solving the multiplication problems by hand. One method would be to give the students paper and pencil or other manipulatives when using the program. Another would be to devise on screen notepads and manipulatives for the students to use. This method would be more effective in maintaining interaction between the student and the program.

Second, we need to develop a method of changing the math problems every time a student restarts the program. The most effective way to accomplish this task is to create a variety of problems and then to script the program so that it randomly assigns one of these problems to the correct screen.

Student Evaluations

Once we implemented our program in the field setting, we asked the students to complete a survey to evaluate the program (see Appendix). This survey focused on three areas: content,

motivation, and design. It also included a section where students could make comments related to their experiences with the program.

The results of the survey were overwhelmingly favorable. All of the students indicated that they understood the purpose of the game, could do the math problems, and could navigate through the program with ease. Eighty-three percent of the users liked the pictures as well as looking for Addy. Ninety-four percent of the students agreed that they would use the program again (see Tables 1,2, and 3 for details).

CHAPTER FIVE: SUMMARY AND CONCLUSIONS

There are times when we as teachers will be faced with a concept that must be taught but for which no appropriate instructional material exists. In this situation, we believe that if it is not out there, then create it. The time spent in creation of this material will be duly repaid in less time spent reteaching a topic as a result of ineffective activities. Some teachers will elect to create instructional materials on their own. Others will choose to make the development of their materials a classroom project.

For those teachers who wish to design their own software, the guidelines presented in our paper will be extremely useful. Combining these guidelines with the learning characteristics and entry behaviors of their students will allow these teachers to create successful instructional software.

More importantly, however, we see this project having ramifications for self-directed, cooperative learning. If students are taught these design principles, they could then be instructed to work in cooperative groups to design a location where Addy could hide. They would need to determine everything from graphics to the problem that the user must solve. They would also have to select incorrect answers that would be viable choices. "Some of the best thinking results when students try to represent what they know. Representing knowledge as a mindful task can be enabled by cognitive tools such as hypermedia construction software" (Jonassen & Reeves, 1996, p.696). Going through this process would ingrain math concepts as well as empower the students to create their own program.

Designing, implementing, and evaluating our program was a beneficial experience for us. We were afforded the opportunity to apply our knowledge of instructional technology and to

gain confidence in our ability to create instructional material to meet a specific classroom's needs. Throughout our careers, we will be faced with the dilemma of fitting a child into "pants" that are either too small or too large. Hopefully, as a result of this experience, we will choose to take the time to design "pants" that are a perfect fit.

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Table 1

Results of student evaluations

3=Yes 2=Not Sure 1=No

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	Y
1	Evaluator	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	Average
2																				
3	Content																			
4	Purpose	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
5	Problems	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
6																				
7	Design																			
8	Navigation	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
9	Pictures	3	3	3	3	3	3	3	2	3	3	3	3	2	3	3	3	2	3	2.8
10																				
11	Motivation																			
12	Looking	3	3	3	3	3	3	3	2	3	3	3	3	2	3	3	3	3	3	2.8
13	Play Again	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	2.9
14																				
15	Average	3	3	3	3	3	3	3	2.7	3	3	3	3	2.5	3	3	3	2.8	3	

Table 2

Average score for each survey question

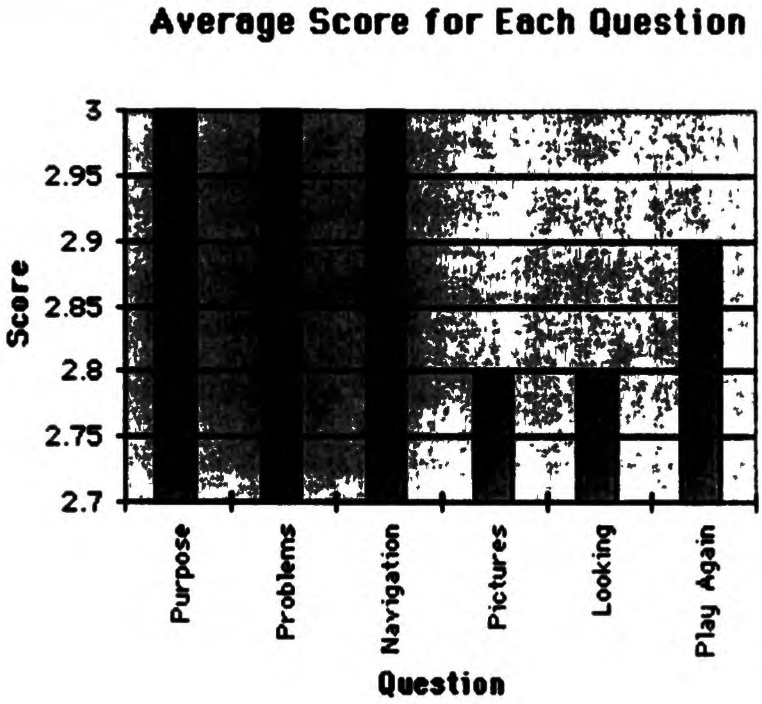
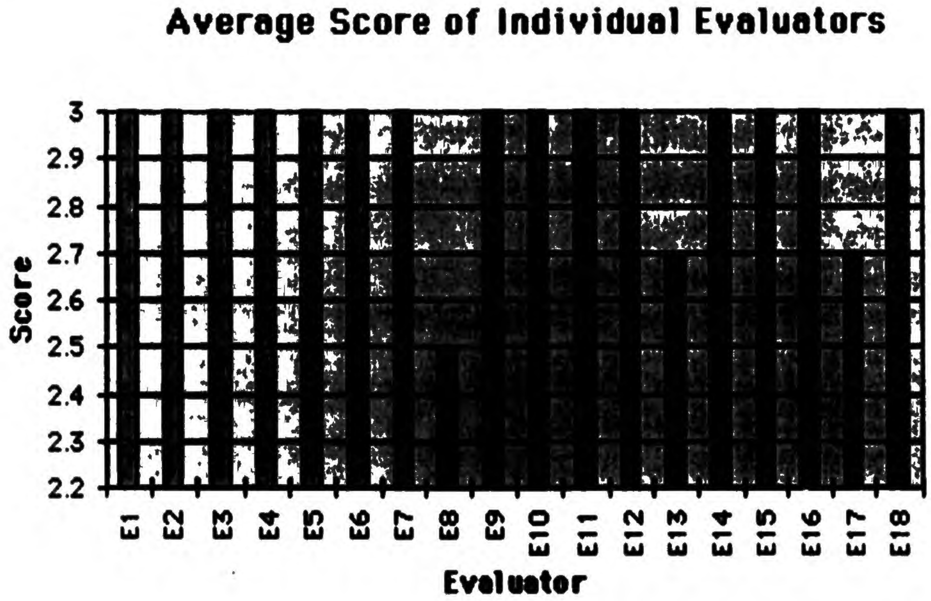


Table 3

Average score of individual evaluators



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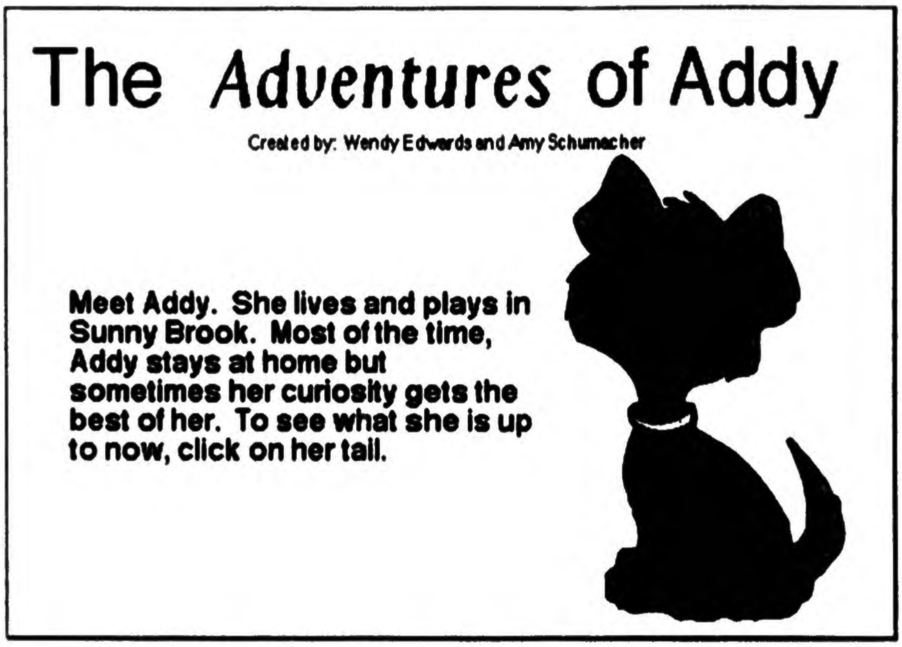


Figure 1

Figure 2

Figure 3

Figure 4

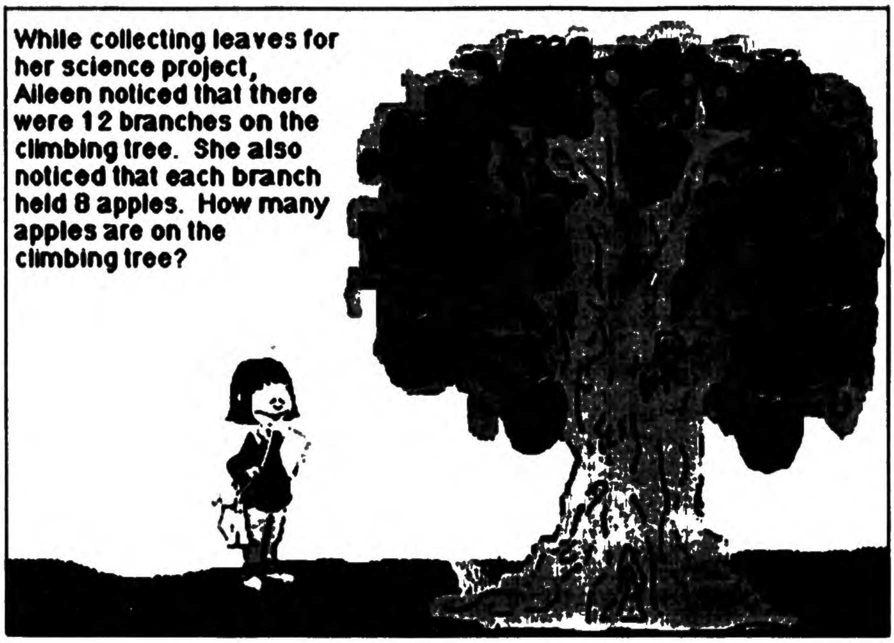
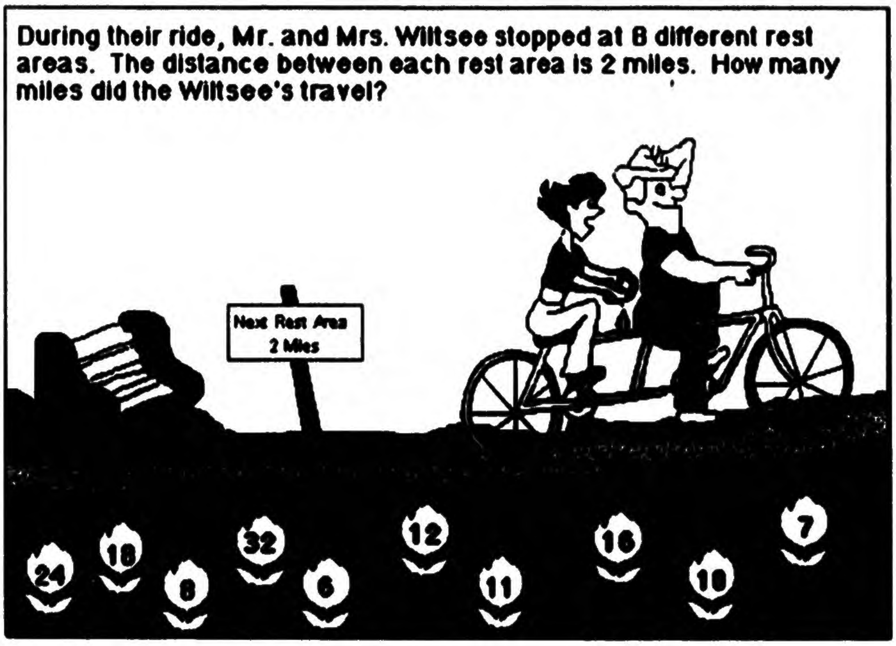


Figure 5



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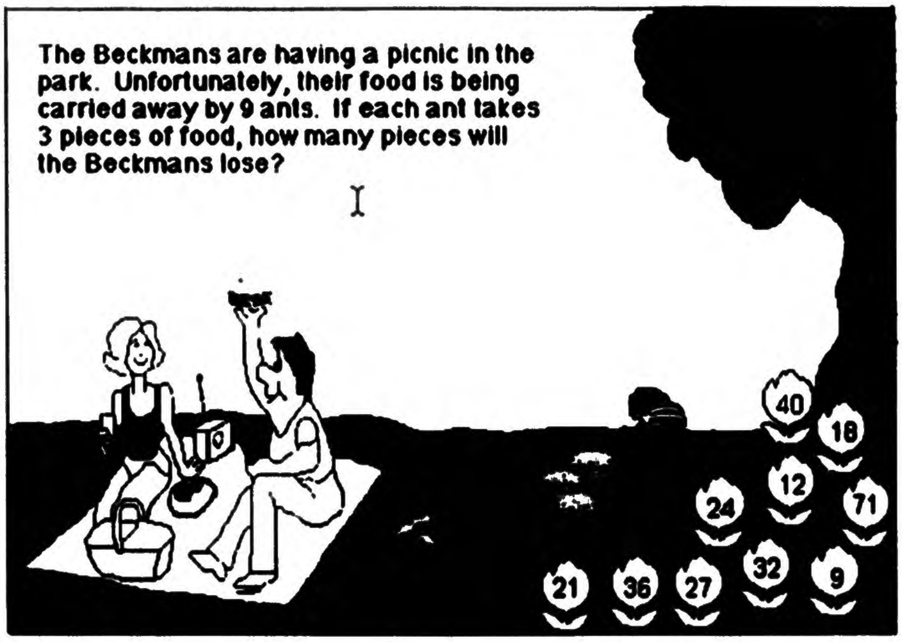

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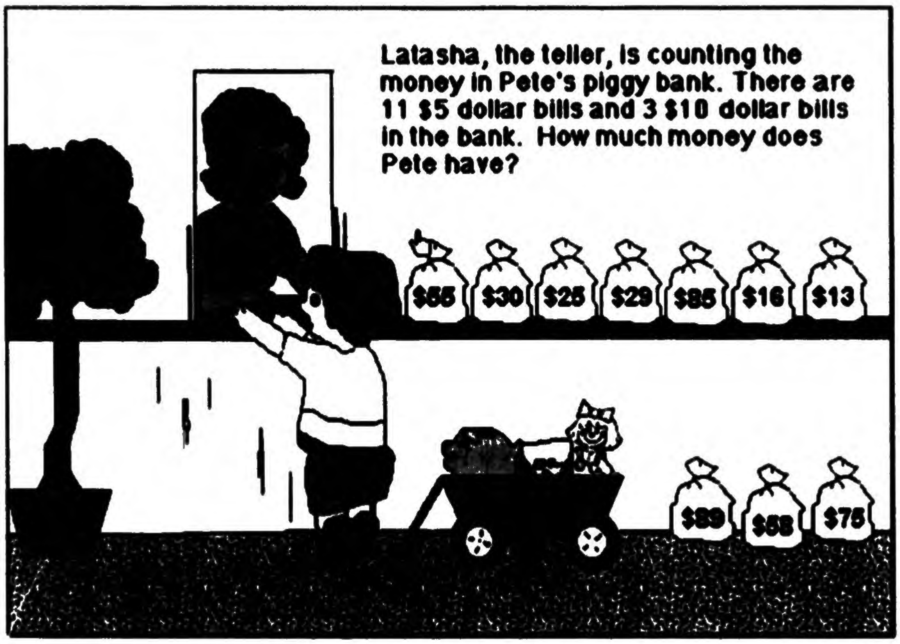

Figure 8

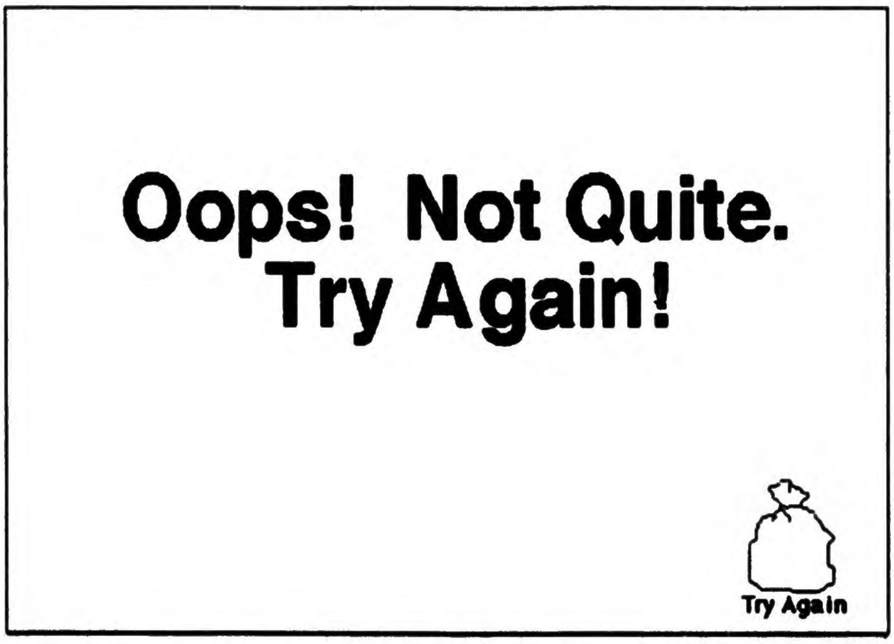

Figure 9

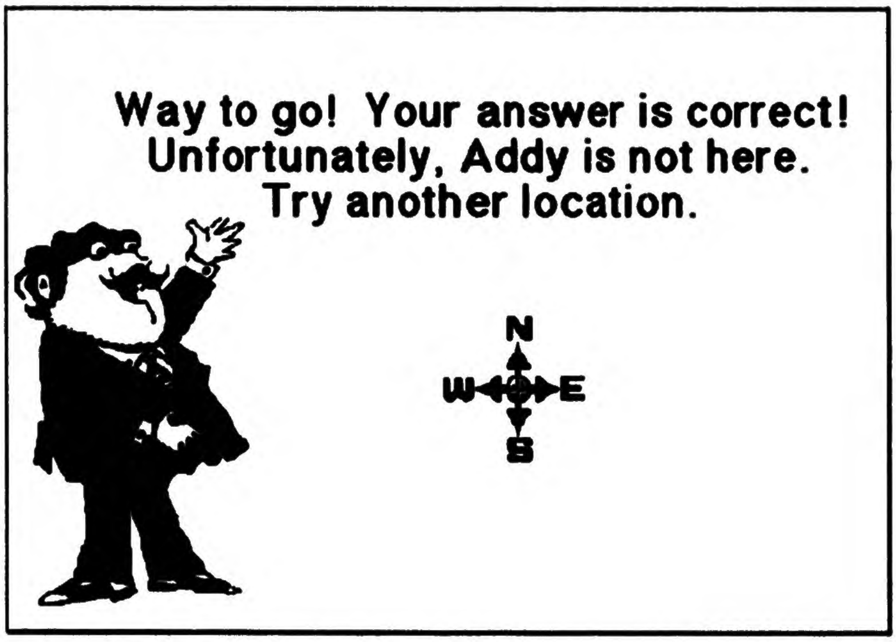

Figure 10

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Appendix

The Adventures of Addy Evaluation Form

1. I understood the purpose of the game.	☺	😐	☹
2. I could do the math problems.	☺	😐	☹
3. I knew how to go from one place to another.	☺	😐	☹
4. I liked the pictures.	☺	😐	☹
5. I liked looking for Addy.	☺	😐	☹
6. I would play this game again.	☺	😐	☹

Comments:

END

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